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Evaluating Federal Urban Forestry Performance Measures in Massachusetts (u.S.A.)

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EVALUATING FEDERAL URBAN FORESTRY PERFORMANCE MEASURES IN MASSACHUSETTS (U.S.A.)

A Thesis Presented

by

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ABSTRACT

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In 2006, the U.S. Forest Service implemented performance measures to evaluate urban forestry management in communities in each state. The Forest Service implemented these measures under its Community Accomplishment Reporting System (CARS). To achieve four CARS measures that pertain to management, communities must have a management plan, professional staff, tree ordinances, and an advisory or advocacy organization. It is unclear whether attaining the CARS measures reflects the status of the urban forest itself. We analyzed street tree inventories from communities in Massachusetts that met the CARS measures. We considered the net gain or loss in the number of street trees in 2007 and cost-benefit analyses from the Street Tree Resource Analysis Tool for Urban Forest Managers (STRATUM). We analyzed the diversity of street tree populations. We used a correlation analysis to discover associations between these variables and both community demographic measures and qualification of the urban forester managers.

Thirty-three communities met the CARS measures and 9 had active street tree inventories. Fewer than half of the communities planted more trees than they removed in 2007. Planting and removal activity increased with tree budget. Cost-benefit analysis showed that for 8 of 9 communities with inventories, benefits of street trees outweighed the cost of management. Community population was associated with trees planted, trees removed, and tree budget. Demographic measures were not associated with tree performance. Tree warden certification did not impact tree condition or diversity, however non-certified tree wardens planted trees at a higher rate than non-certified tree wardens. Tree budgets were higher for communities with certified arborists and for communities with inventories used for management. Results serve as a baseline for future study of the impact of the CARS measures on street tree populations in Massachusetts.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Introduction

Urban and community forest managers can measure urban forest performance at least two ways: by measuring characteristics of trees or by measuring the management of the resource. In 2006, the United States Department of Agriculture, Forest Service (USDA-FS or Forest Service) selected the latter and implemented performance measures to document management performance in communities across the United States (USDA Forest Service n.d.)

Forest Service involvement in urban and community forestry is a relatively recent phenomenon, but the Forest Service has quickly become an important source of funding for urban and community forest managers. A 2002 survey of state urban foresters found that 100% of respondents (n=41) received some funding from the Forest Service (Hauer and Johnson 2008). In fiscal year 2008, the Forest Service budget allocated $17.4 million to its Urban and Community Forestry (U&CF) program, a 38% decrease from 2007 (USDA-FS 2007). This was amended to nearly $27.7 million, but shows that threats to urban forestry funding exist (USDA Forest Service 2009). In the face of shrinking budgets for urban and community forestry, accountability is an important tool for ensuring that existing funds are being used to achieve Forest Service goals.

The United States Congress enabled the Forest Service to work with states and local communities under the Cooperative Forestry Assistance Act of 1978. This permitted the Forest Service to “provide financial, technical, and related assistance to

State foresters […]" and to work with local government to encourage urban forestry programs (16 U.S.C. § 2105). This act led to the creation of the Urban and Community Forestry program, which oversees performance measurement of urban forest programs.

A 2004 congressional report noted that the Forest Service lacked the ability to track state performance and progress related to U&CF programs (U.S House of Representatives 2004). The Forest Service introduced a new system, the Community Accomplishment Reporting System, (CARS) in 2005, replacing the Performance Measurement Accountability System (PMAS) (USDA-FS 2005a). A Forest Service official, in a 2004 congressional report, cited PMAS as inadequate for meaningfully assessing accomplishments (U.S. House of Representatives 2004). Another report the Forest Service commissioned in 2004 on the U&CF program pointed out that PMAS assumes "that if communities create and strengthen programs related to urban forests, then healthy and sustainable urban forests will result" (Hortscience and Aslan 2004). The same assumption also lies at the base of CARS, but CARS is organized at the community level, rather than the state level, facilitating further inquiry. Meeting the CARS measures and reporting them to the Forest Service, however, does not address the *condition* of urban forests across the United States. There is no accounting for diversity, age structure, condition, or for quantifiable environmental and monetary benefits trees provide.

The CARS performance measures the Forest Service adopted included four aspects of urban forestry programs that pertain to management (Table 1.1). These are part of what the Forest Service describes as a "family" of performance measures that includes non-management measures as well, such as volunteer community service hours in urban forestry activities (USDA-FS Service n.d.). These other non-management measures were not considered in this study. Throughout this thesis, the four CARS measures that pertain to management will be referred to as "CARS measures." The Forest Service tracks attainment of CARS measures through a database that state urban forest coordinators access to update information about state programs. The CARS database includes information for urban and community forestry programs across the United States. The Forest Service allocates part of its funding for state urban and community forestry programs according to attainment of the CARS measures (USDA Forest Service 2005). The Forest Service also takes into account other factors such as how much funding a state has received. It is unclear how the Forest Service selected the four CARS measures, as opposed to other measures that might be equally or more informative, such as tree budget, per capita spending on tree care, the number of staff devoted to urban forest management, or measures concerning urban forest structure. Many studies have investigated the prevalence of the CARS measures or similar measures in urban forestry programs across the country (Kielbaso 1990; Davis 1993; Elmendorf et al. 2003; Schroeder et al. 2003; Treiman and Gartner 2004; Ries et al. 2007, Rines et al. In Review). Other studies have described the structure of urban forests (McPherson and Rowntree 1989; Gartner et al. 2002), while some have evaluated environmental functions of urban forests (McPherson et al. 1994; Scott et al. 1998; Xiao et al. 1998; McPherson et al. 2005), and condition of urban forests. [For a comprehensive review of the urban forest of Sacramento, California see *Journal of Arboriculture* 24(2) and 24(4)]. From these studies, however, it is difficult to draw the relative importance of each measure or the aggregate result of using all these measures on an urban forest. A holistic study of these measures and urban forest performance is lacking. Additionally, the CARS measures evaluate management of urban forests, but do not take into account the condition of urban forests. Without known improvements in urban forest resources in communities meeting CARS measures, it is difficult to justify the importance of the measures. It is vital to know if there is a relationship between the CARS measures and urban forest condition.

In 2006, the University of Massachusetts, and the Massachusetts Department of Conservation and Recreation (DCR), conducted a survey to determine the performance of urban forestry programs in Massachusetts. The survey was directed to Tree Wardens. Every community in Massachusetts must have an individual, the Tree Warden, who is responsible for the care of public trees (M.G.L. Ch. 87; M.G.L. Ch. 41). Tree wardens from 143 communities in Massachusetts responded to the survey (a 41% response rate). The survey consisted of twenty questions regarding the position, training, staff, management priorities, and attitudes of tree wardens. From the tree wardens' responses, investigators determined whether a community met one, two, three, or all four CARS measures. Following completion of the study, more communities responded, increasing the overall response rate.

The purpose of the current study is to assess what it means to meet the four CARS measures. The Forest Service refers to communities that meet four CARS measures as "managing communities" which is adopted in this study. This study will address five research questions related to the CARS measures and urban forest performance:

1. Does investing in an urban forestry program provide financial benefit to a community?
2. Are there community demographic variables that are associated with CARS measures?
3. Do managing communities plant at least as many or more trees than they remove?
4. What is the role of arborist certification in tree planting and removal activities?
5. Do managing communities remove dead (and thus hazardous) trees in a timely fashion?

Judicious urban forest management can help maximize environmental, economic, and social benefits of urban and community forests, in addition to reducing tree-related hazards. As communities become more densely populated these benefits increase as does the importance of maintaining a safe urban tree population.

Literature Review

Urban Forests

Urban forests consist of all trees and woody vegetation in an urbanized area, including vegetation on public and private land (Miller 1997). The urban forest is not necessarily a connected grouping of trees, although this does occur, but the agglomeration of trees over an area of relatively dense human settlement (Miller 1997). Dwyer et al. (2003) identified three characteristics of the urban forest: diversity, connectedness, and dynamics, all with management implications. They identified diversity among trees, microclimates, soils, urban infrastructure, and landscape uses. Urban forests connect people with natural resources, buildings with the landscape, and wildlife with urbanized areas. Trees are also connected to a number of urban issues: water quality, air pollution, recreation, and aesthetics. They identified urban forests as a dynamic resource, changing over time. A successful, sustainable management program addresses all of these characteristics. Traditional definitions of sustainability stem from the United Nations Brundtland Commission Report of 1987 that defined sustainable development as “meet[ing] the needs of the present without compromising the ability of future generations to meet their own needs.” (World Commission on Environment and Development 1987). Researchers have refined this to fit forestry and to include other connected elements besides the tree resource. Environmental, economic, and community factors were part of Salwasser’s 1993 definition (Quoted in Clark and Matheny 1997). This is especially important in urban areas where these elements are directly and closely connected with the resource. Dwyer et al. (2003) describe urban forest sustainability as “maintaining healthy and functional vegetation and associated systems that provide long-term benefits desired by the community.”

Clark and Matheny (1997) described sustainability for urban forests. Forming the foundation of their model are three elements. Two of these elements are reflected in the CARS measures: the community framework and resource management. The third element, the vegetation resource, is not reflected in the CARS measures. An urban forest is only sustainable if the resource itself is diverse and provides a meaningful level of benefits (Clark and Matheny 1997; Dwyer et al. 2003). From the CARS measures alone, the state of the urban forest is unknown.

In 1987, the Forest Service and the National Association of State Foresters published guidelines for *Effective Tree Care Programs* (Hanson et al. 1987, as cited in

Davis 1993 p. 201-202). These guidelines included numerous provisions, some of which the Forest Service integrated into the CARS program. These guidelines, however, go beyond the CARS measures and include, among other concepts, outreach to the community, a dedicated budget that is funded by more than one source, a tree planting program, use of local media, inclusion of developing areas in tree management programs, and local citizen participation in tree care activities (cited in Davis 1993). These guidelines include many elements of Clark and Matheny's (1997) model for sustainability, with emphasis placed on the community facet of urban forestry and the management of the resource.

While many studies focus on management programs or elements of management (Kielbaso 1990; Reeder and Gerhold 1993; Vitosh and Thompson 2000; Dickerson et al. 2001; Elmendorf et al. 2003; Schroeder et al. 2003; Treiman and Gartner 2004; Kuhns et al. 2005; Hauer and Johnson 2008; Lewis and Boulahanis 2008; Stevenson et al. 2008) fewer focus on the structure and condition of urban forests (McPherson and Rowntree 1989; Davis 1993; Galvin 1999; Gartner et al. 2002; Xiao 2002; Galvin and Bleil 2004; McPherson et al. 2005). In a survey of urban forestry in Pennsylvania communities, Reeder and Gerhold (1993) asked respondents about the condition of the urban forest and the results give some idea of the perceived and/or actual quality of the urban forest. Elmendorf et al. (2003) also asked about the occurrence of systematic tree care and the importance of systematic tree care in Pennsylvania communities. They found that often actions did not live up to attitudes. Davis (1993) also examined urban trees through assessment of tree inventories for communities in Kansas. Through his assessment he evaluated urban forest composition and trends toward increasing diversity, and also trends in planting activities to identify communities that were increasing the urban forest resource. Davis found mixed results among communities with inventories. In some areas, the street tree population was improving, and in others, it was deteriorating. Galvin and Bleil (2004) examined the urban forest resource in their assessment of canopy cover and its relation to demographic measures in Maryland.

Benefits of Urban Trees

Urban trees help mitigate many environmental problems common to urban areas. [For a broad review of benefits, see Nowak and Dwyer (2007).] Two major environmental benefits of urban trees are reduction of stormwater runoff and air pollution. Urban trees intercept rainfall on leaves, branches, and bark, reducing subsequent runoff by slowing the flow rate. This service has economic value as well as environmental value. In Santa Monica, California the reduction in flood control costs and the avoided costs for treating intercepted stormwater totaled $110,980 (Xiao and McPherson 2003), and in Modesto, California, stormwater benefits were greater than $600,000 (McPherson and Simpson 2002). Trees mitigate urban air pollution directly, by temporarily retaining pollutants on leaf surfaces and reducing peak flow, and indirectly, by reducing air temperatures and hampering the formation of ozone. Trees can also reduce heating and cooling needs for buildings, which reduces pollutant emissions at the point source of electricity generation (Nowak et al. 2006).

Urban and community forests also provide social and economic benefits (Dwyer et al. 1992; McPherson et al. 2005). The environmental services described above have economic value through avoided costs that a community would otherwise incur. Urban trees also provide economic benefits through increased residential property values

(Morales 1980; Martin et al. 1989). This aesthetic benefit also positively impacts for business owners in well-planted business districts where consumers prefer to spend more time (Dwyer 1992; Wolf 2003; Wolf 2004).

Researchers have been developing methods to quantify benefits of urban forests. Many studies have quantified the value of the urban forest as a whole using methods from economics such as the public's willingness to pay for tree care programs. Such valuation indirectly assesses the value of the resource, but complicating factors such as differences between perceived willingness to pay and actual behavior or misstating willingness to pay in circumstances where that value may be used to levy new taxes or otherwise pay to manage a resource limit the method's rigor (Field and Field 2002). More recently, methods have focused on putting a dollar value on the environmental services urban forests provide, either through costs of controlling pollution or costs of mitigating damage ("damage value"). Wang and Santini (1995) describe these two methods in detail for quantifying the cost of air pollution. For air pollution, calculating control costs is a two-step process that first begins with identifying the marginal control measures. This method assumes that the marginal control measures represent the ideal for air quality standards. The second step is to calculate the cost of those measures. The underlying assumption is that the marginal control cost equals the marginal damage value for the pollutant. This assumption, however, is not realistic based on all that goes into government-established emissions standards. This method is simpler than calculating the costs for mitigating damages which is a lengthy process that involves many steps: recognizing emissions sources, estimating emissions, and estimating health effects and costs of treatment. It is difficult to take into account all assumptions, effects, and costs, making this a difficult mode for estimating costs (Wang and Santini 1995; Field and Field 2002).

For several years, researchers at the Forest Service and cooperating agencies have been developing software to determine environmental benefits provided by trees of different species growing throughout the United States. One program is the Street Tree Resource Analysis Tool for Urban Forest Managers (STRATUM), which is currently bundled in the i-Tree software suite. STRATUM calculates environmental and monetary benefits of trees. From species and diameter at breast height (dbh measured 1.37 m from the ground), STRATUM estimates environmental services and concomitant economic value provided by a particular tree. STRATUM then sums the services and values from all trees in the community. [For more detailed information on STRATUM, see McPherson et al. (2007).]

The Forest Service intended the STRATUM program to be accessible for urban forest managers. With that in mind, there are only two urban forest inputs that managers have to enter into the program: species and dbh. At the most general level, STRATUM calculates environmental information including benefit prices based on regional default values. Users select their region and the program defines prices for various pollutants: CO_2, PM10, NO_2, SO_2, volatile organic compounds, and stormwater. STRATUM also calculates avoided electricity and heating costs based on local average electricity and natural gas prices.

The ability of urban forests to provide environmental benefits is increasing in importance as more areas across the United States become urbanized. Massachusetts is the fourth most urbanized state, with 34.2% of its land described as urban (Nowak et al.

2005). With increasing urbanization comes the conversion of land from agriculture or forest to housing, roads, and other infrastructure for people, buildings, and vehicles—and subsequently, increased pollution. Even with these pressures and the potential benefits of a well-maintained urban forest, many communities are lacking adequate urban forest management programs. In 2003, 90% did not have programs performing at the sustained level, the highest level of performance, under the Forest Service PMAS reporting scheme. The sustained level designated programs that functioned with community support and municipal activity to systematically manage urban forests and natural resources in communities (Hauer and Johnson 2008).

Urban Forest Performance Measures and Community Demographics

The nature of urban forest management programs is often associated with community demographics. Across the United States, communities with greater population often have more elements of a comprehensive tree program (Dickerson et al. 2001; Schroeder et al. 2003; Kuhns et al. 2005). This association also held true in Massachusetts (Rines 2007). In addition to population, population density has been correlated with urban forest management performance. Reeder and Gerhold (1993) showed that cities in Pennsylvania were more likely to have tree programs than less populated townships and boroughs. Larger communities in Missouri were also more likely to have urban foresters with a degree in forestry or a related field (Treiman and Gartner 2003).

Among small southern towns, the most important predictor of urban forest performance was the presence of a tree department with an urban forester and a dedicated budget, not affluence and education level of residents (Lewis and Boulahanis

2008). In New Jersey, Tate (1984) showed that communities felt that they could not provide the most favorable tree care because of insufficient funding. Research has also shown associations between community demographics and presence of professional staff in tree management programs. In Maryland, canopy cover, as a measure of urban forest quality, was correlated not with population, but with the area of a municipality (Galvin and Bleil 2004). Researchers detected these and other patterns as they relate to the CARS measures that the Forest Service adopted.

Tree Inventories and Management Plans

A tree inventory can be a tool for justifying tree care funding and increasing work efficiency in communities (Tate 1985), but is frequently lacking in municipal management programs (Kielbaso et al. 1982; Reeder and Gerhold 1993; Elmendorf et al. 2003; Schroeder et al. 2003). Recent evidence, however, indicates that more communities are conducting inventories. In Utah, the number of communities with inventories has doubled since the 1990s (Kuhns et al. 2005), while in California, the percentage of communities with inventories has increased to over 80% (Thompson 2006), and in Oregon, to 56% (Ries et al. 2007). In Massachusetts, 62% of communities reported that they had tree inventories (Rines 2007). In Utah, the use of inventories was more common in communities with populations greater than 10,000 (Kuhns et al. 2005).

In Massachusetts, management plans were the least likely CARS measure for communities to meet. Approximately 1/3 of responding communities reported having a management plan in the 2006 survey and this was positively associated with population (Rines 2007). Utah showed similar levels of attainment for management plans (Kuhns et al. 2005). There have been associations between population and adoption of management plans elsewhere in the United States. In Pennsylvania, communities with more than 20,000 inhabitants were more likely to have adopted a management plan than communities with fewer than 2,500 people. For communities in between, however, the trend was not clear with medium-sized communities (between 5,001-10,000) more likely than communities in the next highest population tier (10,001-20,000) to have a management plan (Stevenson et al. 2008). Among cities in Oregon, only 9% had a management plan (Ries et al. 2007). Sometimes municipal officials view tree management plans as important (Elmendorf et al. 2003), but in Massachusetts, only 56% of tree wardens agreed or strongly agreed that management plans were important (Rines 2007).

Professional Staff

In larger communities in Illinois, the person in charge of managing urban trees was more likely to be certified or have a degree in urban forestry or a related field. In small communities, however, the principle urban forest manager did not have any formal training in the care and maintenance of trees (Schroeder et al. 2003). Trends in Oregon were similar. There, as community size increased, so did the likelihood of ISA-Certified Arborists on staff. Only 26% of small communities had an ISA-Certified Arborist, either as a manager, on staff, or on contract, but 100% of large cities did (Ries et al. 2007).

Tree Ordinances

Less populous communities in Illinois were less likely to have comprehensive tree ordinances (Dickerson et al. 2001; Schroeder et al. 2003). Dickerson et al. (2001) also showed that some provisions of tree ordinances were associated with affluence and education. In Oregon, 62% of cities had a tree ordinance (Ries et al. 2007). While 73% of communities in Pennsylvania had a tree ordinance, only 28% had systematic tree programs, raising some doubts about the ability of communities to enforce tree ordinances (Reeder and Gerhold 1993). Ordinances were correlated with population in Pennsylvania. Communities of greater than 20,000 people were almost twice as likely to have ordinances than communities of fewer than 2,500 (Stevenson et al. 2008). The same was true in Utah (Kuhns et al. 2005), where the percentage of communities having an ordinance increased with community size.

Advocacy and Advisory Organizations

Usage of advisory or advocacy organizations varied across the United States. In Utah, 23% of communities had a shade tree commission or tree board (Kuhns et al. 2005). While the authors did not correlate this with population, they speculated that smaller communities might not be able effectively to take advantage of support. In California, however, approximately 80% of incorporated cities and counties reported having a tree board, but this figure dropped to 25% when focusing on advocacy organizations (Thompson 2006). In Pennsylvania 57% of communities indicated that they had a shade tree commission and that nearly 90% met at least once a year (Elmendorf et al. 2003). In Oregon, cities were 20% behind with 38% of cities in 2004 reporting existence of an advisory organization (Ries et al. 2007).

Table 1.1. USDA Forest Service, Urban & Community Forestry Program Performance Measures (USDA-FS, CARS Glossary)

Management Plans: A detailed document or set of documents, developed from professionally-based inventories/resource assessments, which outline(s) the future management of the community's trees and forests. The plan must be active (i.e., in use by the community and updated as needed to incorporate new information).

Professional Staff: Individuals who have one or more of the following credentials, and who the community directly employs or retains through written agreement to advise and/or assist in the development or management of their urban and community forestry program: 1) a degree in urban forestry or a closely related field (e.g., forestry, horticulture, arboriculture, etc.), and/or; 2) International Society of Arboriculture Certified Arborist (ISA) or equivalent professional certification.

Ordinances/Policies: Statutes or regulations that direct citizens and local governments in the planting, protection and maintenance of urban and community trees and forests.

Advocacy/Advisory Organization: Organizations that are formalized or chartered to advise (organizations established by the local government) or advocate or act (non-governmental organizations active in the community) for the planting, protection and maintenance of urban and community trees and forests.

CHAPTER 2

METHODS

Community Selection

The 33 communities selected for this study had met the four Forest Service CARS measures (Rines 2007 and MA-DCR). After Rines (2007) published his work, 11 more communities that met the CARS measures responded and were included in the present study. The study consisted of 22 towns and 11 incorporated cities in Massachusetts. The project had three stages: demographic analysis of the 33 managing communities, data collection from tree wardens, and analysis of street trees from inventories collected from tree wardens.

Data Collection

Data collection consisted of speaking with tree wardens to obtain basic information about community tree programs and acquiring a copy of the tree inventory. Individual inventory information was collected under the agreement that inventory information would be presented in aggregate and that individual results would not be made public. Due to difficulties reaching tree wardens by telephone or by e-mail, in-person collection was initially preferred to other methods because of the ability to handle questions regarding inventories. In January 2008, the Massachusetts Department of Conservation and Recreation (DCR) sent an e-mail to all 33 tree wardens. The initial contact introduced the project and informed the tree warden that a graduate student would contact them requesting information and a copy of the community tree inventory. To reach tree wardens who did not use e-mail, the content of the e-mail was also sent by mail to contact addresses that DCR had for each tree warden. Five business days after

DCR sent the notification e-mails and mailed the letters, telephone calls to tree wardens began. Beginning in January 2008, tree wardens were telephoned to gather preliminary information and to set up meetings. Following the initial telephone calls, it was apparent that some tree wardens on the DCR contact list had left their positions. In these instances, and where tree wardens did not return calls, town halls or appropriate town departments were contacted by telephone to acquire current information and to contact other people working with the urban forestry program who have access to tree information. Tree wardens, or their department, when no specific tree warden information was available, were called up to three times. Meetings began in January 2008 and consisted of a minimum of eight questions (Appendix A).

The intent of in-person meetings was to aggregate inventory information and ensure that tree wardens shared information that they may have been less likely to share without knowing the recipient. The meetings also afforded a special opportunity to speak with tree wardens and delve a little deeper into their program's use of the CARS measures. Tree wardens could offer their thoughts on the importance of the various measures in their communities (Appendix B). Additionally, as communities conduct inventories in various ways, using different codes and abbreviations, the in-person approach was intended to minimize subsequent confusion, as the tree warden could readily answer questions about the inventory. This concern, however, was unfounded as most inventories did not require explanation and tree wardens easily answered questions by phone and email and readily discussed aspects of their community's urban forest management.

Since some communities did not have inventories suitable for the STRATUM analysis (described below), not all inventories were used. To provide reliable STRATUM output, inventories must have been either a complete or a random sample of street segments of the community. It was presumed that the 33 communities had tree inventories as they all stated that they had management plans, which, by Forest Service definition, were based on inventories or resource assessments. The reality, however, was that the type of inventory, purpose of the inventory, and the timeframe in which an inventory was last updated varied. The concern that tree wardens might not be willing to share their inventories and program information with a stranger was unfounded, as tree wardens readily shared information. Consequently, and with few exceptions, interviews were conducted by telephone and inventory information was exchanged by e-mail. Anticipated confusion with and difficulty interpreting inventory data was similarly unfounded, further negating the need for in-person meetings.

Not all communities maintained a record of the numbers of trees planted and removed. Tree wardens who could provide a range of trees planted or removed ± 30 trees were included in the analysis. One community had records for trees planted over a multi-year period and these were averaged for an annual planting rate. The tree warden in this instance also confirmed that tree planting effort was approximately even over the course of his tenure in that position. Unbounded and ballpark estimates were not included in the analysis. Some communities did not have all the inventory or tree data or did not respond to requests for information. Where possible, missing information on tree plantings and tree budget was taken from Tree City USA (The National Arbor Day Foundation) documentation that communities filed with the DCR.

Inventories

Tree wardens, professional companies, and volunteers conducted tree inventories. Collected data varied among communities, but all communities recorded species and dbh, and most recorded condition. Some inventories were complete and others were based on random and non-random samples. Of the sample inventories, one was based on randomly selected street segments, comprising 10% of the community roads; one sample was not random, consisting only of street trees in a downtown area; the third sample consisted of 85% of the community's trees. These inventories were included in the inventory analysis. Data were normalized to a per-tree value to account for different inventory scenarios. Communities with usable inventories (n=9) are subsequently referred to as "inventory communities."

Inventory Analysis Using STRATUM

Tree inventories were used to determine the structure, condition, and environmental benefits of the urban forest and were analyzed using STRATUM (version 2.0, i-Tree, Kent, OH). In addition to meeting criteria for STRATUM analysis, tree inventories must have been updated within the last five years. Other categories useful for the analysis were condition and hazard ratings.

Developed by the Forest Service and partners, STRATUM is a software program that models the benefits provided by street trees (McPherson et al. 2007). In particular, it provides benefit-cost values based on attributes of trees (size, species), their location, and local cost data for environmental services such as stormwater treatment and avoided heating and cooling costs. Since this study focused on street trees, STRATUM was the preferred choice for analysis. STRATUM accepts inventories as Microsoft Access databases and does not require any Geographic Information System (GIS) information.

Inventories were not consistently formatted and individual inventories often contained different data fields than other inventories. Most inventories required formatting before they could be input to STRATUM. Species codes in many inventories had to be altered to the codes that STRATUM recognized, but some less common species had to be entered manually as STRATUM recognizes only 200 species codes per geographic region. Unless STRATUM designated a cultivar (such as Crimson King Norway maple *Acer platanoides 'Crimson King'*), trees were only identified to species. For calculating the 10 most common species for inventory communities, cultivars were not reported and where applicable, were presented only to species. Extraneous data from inventories were removed prior to input into STRATUM.

To normalize tree information from inventories that focused on one particular area of a community, such as a downtown, environmental services and economic value were analyzed on a per tree basis. One community had a non-random sample and two communities had inventories with 85% or more of the linear miles of street inventoried. While STRATUM can produce results based on a random sample of street segments, trees from one area of a community, such as a downtown area, may over or understate performance of the urban forest as a whole, so per-tree figures were used to maximize the use of inventories.

Tree size-class distribution was analyzed using median values for size classes. STRATUM divides dbh into nine size classes using 3 to 6-inch (7.62-15.24 cm) increments. Median value for communities was selected due to skewed distribution among dbh for size classes determined visually by examining boxplots (Quinn and Keough 2002). Median values for size classes were plotted and tested for skewness using the D'Agostino Test (D'Agostino 1970).

STRATUM calculated several response variables from tree inventory data. Two explored in depth here include Importance Values (IV) and Relative Performance Index (RPI). Importance values indicate reliance on a particular species. STRATUM calculated this value for species that comprise 1% or more of the total street tree population:

$$IV = \frac{(n_T/N_T + n_L/N_L + n_C/N_C)}{3}$$

where n reflects the value for a particular species, N reflects the value for the total population of trees, and the subscripts C, L, and T represent total canopy area, total leaf area, and total individuals, respectively. The maximum IV is 100, which indicates complete reliance on one species.

The Relative Performance Index (RPI) compares the condition of a species relative to the condition of other species. The center of this measure is one. If a species performs below average, indicating that it has more trees in lower condition classes, RPI is less than one. If a species has trees in higher condition classes than average, it has a value greater than one. RPI does not take size classes into account (i-Tree 2008).

Explanatory Variables for STRATUM Analysis

STRATUM required user input of several demographic and environmental explanatory variables. The Forest Service calculated benefit prices for pollutants based on avoided costs of emissions that were determined from the marginal damage cost in a process outlined in Wang and Santini (1995). The current study relied on default values from STRATUM for air pollutant costs. For stormwater management costs, the estimated cost for treating a gallon of sewerage for Boston was used for all communities. For electricity and natural gas rates, averages for 2008 were used for utilities providing service to each managing community.

Seven community characteristics were entered into STRATUM: city name, total municipal budget, population, total land area, average street width, average sidewalk width, and total linear miles of street. Municipal budget information was for fiscal or calendar year 2007 and was collected from town annual reports, and in a few instances from town clerks or treasurers. Tree budget data pertained to fiscal or calendar year and were collected from town annual reports, town clerks, and applications for Tree City USA that communities file with the DCR. Communities are required to submit tree budget data when applying for or renewing their Tree City USA status, so the data were used as a last resort when other sources were not available. Tree City USA budget data were used to calculate the amount of money communities spent on tree planting. Populations for each community were from the 2000 U.S. Census. Land area figures were from American Factfinder (U.S. Census Bureau 2009). Average street width, average sidewalk width, and total linear miles of street were obtained from the tree wardens or public works department, except in the case of one community, where these figures were unknown. For this community, values were calculated using ArcView (version 9.2, ESRI, Inc., Redlands, CA). Town and road layers from MassGIS (www.massgis.gov) were used to quantify these values. For quantifying aesthetic value of trees, STRATUM required average home resale values. For these analyses, 2007 median sale price for single-family homes in each managing community were used from a study by The Warren Group (2008).

Diversity

Diversity was calculated using the reciprocal of Simpson's (1949) index. Researchers have used Simpson's index (or its inverse or reciprocal) to quantify diversity in urban forests (Sun 1982; Gartner et al. 2002; Maco and McPherson 2003; Thompson et al. 2004). Simpson's index (D) was chosen because it is a dominance index and inventory data revealed that tree diversity typically reflected the dominance of a few species. D represents the probability that two randomly selected individuals from a population will be the same species (Magurran 1988). As the index value increases, diversity increases as well. The index accounts for the number of species present as well as abundance of each species. Shortcomings of this index have been recorded (Magurran 2004), but it provides a point of comparison for inventory communities as well as with other studies. The reciprocal of D was selected for its greater discriminant ability over D [see Magurran (1988) for a complete explanation].

Statistical Methods

Demographic data from managing communities were compared using the non-parametric Wilcoxon Rank-Sum test (Zar 1999) to examine the distribution of demographic data from selected communities to assess how the distribution differed from Massachusetts as a whole. Six demographic variables were considered: population, population density, land area, percentage of population with a bachelor's degree, median household income, and population change from 1990-2000. The Wilcoxon Rank-Sum test was not an exact comparison, but gave a sense of how the distribution of demographic parameters of managing communities differed from the state.

The Wilcoxon Rank-Sum Test was used to test: 1) tree budgets for managing communities with and without inventories used for management ("managing inventories") and 2) tree budgets for communities with and without certified tree wardens among managing communities. For managing communities, significance was determined at alpha = 0.05. For inventory communities, due to the small sample size, significance was determined at alpha = 0.10 (Mendenhall et al. 2006).

Due to non-normality of community data, the non-parametric Spearman's rank correlation coefficient (ρ_s) was used to assess existence, direction, and significance of relationships between variables (Zar 1999). For managing communities, Spearman's rank correlation was used to assess relationships between 1) demographic variables (population, median household income, and percent with bachelor's degrees) and a) trees planted b) trees removed; 2) demographic variables (population, median household income, and percent with bachelor's degrees) and tree budget.

For inventory communities, the non-parametric Spearman's rank correlation was also used to assess relationships between 1) trees planted and a) tree condition b) diversity c) tree size class distribution; 2) trees removed and a) tree condition b) diversity c) tree size class distribution; 3) tree budget and a) tree condition b) diversity c) tree size class distribution 4) demographic variables (population, median household income, and percent with bachelor's degrees) and a) tree condition b) diversity c) tree size class distribution.

Pearson's chi-square test was used to investigate the relationship between managing inventories and arborist certification. Significance was determined at alpha = 0.05.

To investigate which parameters best predicted the number of trees planted and removed, as well as the net change (i.e., trees planted – trees removed), an Analysis of Covariance (ANCOVA) was used including a category for whether tree wardens were certified by the International Society of Arboriculture (ISA) or Massachusetts Certified Arborist (MCA) programs in addition to the continuous covariate of a community's tree budget. Although including whether a community had attained Tree City USA status as a second classification in the ANCOVA was originally intended, nearly all communities had attained Tree City USA status, negating its merit.

Initial data associations were revealed through use of a correlation matrix in Microsoft Excel 2003 (Microsoft Corporation, 2003). Associations with r-values higher than 0.5 were further investigated. With the exception of the ANCOVA, all analyses were performed using R (Version 2.7.1, R Foundation for Statistical Computing, 2008). The ANCOVA was performed under the GLM procedure in SAS (version 9.1; SAS Institute, Cary, NC). Tree budget and municipal budget were significantly associated, so tree budget alone was used for correlation analysis.

CHAPTER 3

RESULTS

Participating Communities

From the initial pool of 33 managing communities 30 had records for tree planting, tree removal, or both. Of thirteen communities that had inventories used for management, only the nine inventory communities had inventories suitable for STRATUM analysis. Several other communities had some type of inventory (Table 3.1). Three communities did not respond to inquiries, but data were still compiled for these communities from town annual reports and Tree City USA applications filed with the DCR.

Managing Communities

Geography and Demographics

Managing communities were distributed across the state, with all but two counties represented, Nantucket and Franklin. There was a cluster of eight communities around the Boston metropolitan area, the only location where more than three adjacent managing communities was found (Figure 3.1). The 3 most populated cities in Massachusetts were managing communities, and with the other 30, represented roughly 28% of the total Massachusetts population and 9% of Massachusetts's 351 towns and cities. Managing communities had greater population and population density, but a smaller percentage of residents with a bachelor's degree than all communities in Massachusetts (Table 3.2).

Plantings and Removals and Tree Budget

Not all tree wardens maintained a record of trees planted and removed: 25 communities maintained a record of trees planted and removed, while 2 other communities had a record of either trees planted or trees removed, but not both. Eight communities planted more trees than they removed, fifteen planted fewer than they removed, and two communities had no net change. Although the median number of trees planted and removed was the same, the range for the number of trees removed was more than twice as large as that of trees planted (Table 3.3). The median ratio of trees planted to trees removed indicated that communities planted less than 1 tree for every tree removed (Table 3.3).

As a percentage of the municipal budget, annual tree budgets comprised an average of 0.2%, but exhibited a large range (Table 3.3). Annual tree budgets per capita ranged from $0.00 to $16.61 with a median of $5.63. Four communities fell below the $2.00 per capita spending required by The National Arbor Day Foundation to be eligible for Tree City USA status.

Associations Between Demographics and Tree Budget, Planting and Removal

The number of trees planted increased with the number of trees removed, and both increased with greater tree budget (Table 3.4). The only demographic variable associated with tree planting, removal, and tree budget was population (Table 3.4), but per capita tree budget was not related to population (ρ_s=0.1892, p=0.3236). Communities with managing inventories had greater annual tree budgets than those without managing inventories (Figure 3.2). Similarly, communities with tree wardens who were certified arborists had greater tree budgets than those with tree wardens who were not certified arborists (Figure 3.3). However, communities with a managing inventory did not necessarily have a tree warden who was a certified arborist (chi-square = 1.4596, df = 1, p = 0.2270).

Associations Between Tree Budget and Tree Planting and Removal

As tree budget increased, so did the number of trees planted and removed (Table 3.4), but the relationship between budget and the number of trees planted was confounded by whether or not a community's tree warden was a certified arborist (Figure 3.4). Curiously, no town had an annual tree budget between $500,000 and $1.4 million, and there was a wide range in the number of trees planted and removed for annual tree budgets between $200,000 and $500,000. Thus, the precise nature of the association between tree budget and the number of trees planted and removed was unclear (Figure 3.5). This was presumably because of the confounding effect of population, which was closely associated with annual tree budget, as well as the number of trees planted and removed (Table 3.4).

Tree Warden Credentials

Normalized for differences in area between communities, the number of trees planted per dollar of annual tree budget was greater for communities whose tree warden was not a certified arborist, and this effect was most noticeable in communities with larger budgets (Figure 3.4). In communities for which the tree warden was not a certified arborist, the number of trees planted per square km was not related to budget (Figure 3.4). In contrast, the number of trees removed per square km increased with budget, and the relationship was similar whether or not a community's tree warden was a certified arborist. Models predicting net change in trees per square km were not significant.

Inventory Communities

Geography

The nine communities with inventories represented roughly 20% of the Massachusetts population. The nine communities were distributed over six counties: three counties with one community each and three counties with two communities each. Six communities were in the Boston metropolitan area, with the remaining 3 scattered throughout the state. There were notable absences in western Massachusetts, and areas north and south of Boston.

Inventories

Two communities with old inventories had plans to update them and only one community without an inventory was planning to conduct an inventory for active use. Two tree wardens from communities with old inventories indicated that they did not require inventories because their communities were either small or did not have enough town-managed roads, or because the tree warden was able to drive through all parts of the community to observe the condition of trees.

Resource Structure

Tree size classes for inventory communities were normally distributed (Figure 3.6). Skewness of the distribution (0.3579) was not significant ($p = 0.3372$). The greatest proportion of trees was between 15 and 46 cm dbh. Trees larger than 46 cm began to decrease in proportion of total trees. The difference between trees greater and less than 46 cm dbh was significant. Significantly more trees (W=78, p=0.0003) were $\leq$46 cm dbh than > 46 cm dbh.

Median canopy cover calculated as a percentage of linear miles of street was 18%. Total tree species per inventory community ranged from 26 to 126. The number of species increased with the land area of a community ($\rho_s = 0.7500$, $p = 0.0663$). The Reciprocal Simpson Index showed that diversity both for species and genera was relatively high, although diversity dropped when examining populations by genus (Table 3.5). For genera, the median reciprocal Simpson index was 42% less than the median reciprocal Simpson index for species; for one community the decrease was over 66% (Table 3.5).

Tree inventories indicated a heavy reliance on a few species. The most common species for eight of nine communities was Norway maple (*Acer platanoides*). Red maple (*Acer rubrum*), littleleaf linden (*Tilia cordata*), honeylocust (*Gleditsia triacanthos*), and northern red oak (*Quercus rubra*) were among the other predominant species and were among the top five most common species for four or more communities. Some species were distributed across many communities. Aggregating the 10 most common species for inventory communities showed that 20 species were among the 10 most common in at least 1 community (Figure 3.7). While widespread across communities, many of these species did not make up a large portion of the street tree population of any single community. In some instances, however, one species comprised more than ten percent of a street tree population in a given community.

Importance Values (IV) from STRATUM indicated that, for a few communities, the most frequently occurring species provided the bulk of environmental services

(Figure 3.8). The mean IV for the 5 most common species accounted for approximately 30% of the environmental services for a community. Importance values for each community's 5 most common species ranged from 1.51 to 79.5. The most common species had the highest importance values, more than double the second most common species. By the fourth most common species, importance values fell to less than ten.

The most common species for inventory communities had the lowest Relative Performance Index (RPI) value, meaning that it performed the least well. Plotting RPI and IV together showed that as IV decreased, the RPI increased (Figure 3.8). As species groups provided fewer environmental services, their performance improved.

Tree Condition

Eight inventories recorded tree condition, although some individual entries from each of the eight inventories did not contain condition information. The number of trees for which condition was not recorded, however, comprised, on average, 0.70% of the total street tree population for the 8 communities. Tree condition was not normally distributed across condition classes (Figure 3.9), however, the distribution of trees within each condition class was normal. As trees declined in condition, variation among classes decreased, with the least variation among dead and dying trees.

Examining tree condition by size class showed that trees 15 cm dbh and smaller were mostly in good condition, but the percentage of trees in good condition consistently declined for larger trees (Figure 3.10). In contrast, the percentage of trees in fair condition was greater than the percentage of trees in good condition for all size classes greater than 15 cm dbh (Figure 3.10). The percent of trees in poor condition never exceeded 22% of a particular size class, and there were very few dead or dying trees in any size class (Figure 3.10).

Benefits

Benefit-cost analysis showed that all but one of the inventory communities received more in benefits than it paid in costs. The median benefit-cost ratio per tree was a return of $3.23 for every dollar spent (Table 3.5).

Demographics

Demographic variables were not associated with diversity, tree condition, and size class distribution, with two exceptions. The percentage of trees with dbh between 30-46 cm increased in communities with greater population (Table 3.6). Additionally, the percentage of trees in good condition increased as the percentage of a community's residents with a bachelor's degree increased (Table 3.6).

Planting and Removals

Unlike managing communities, plantings and removals for inventory communities were not significantly associated ($\rho_s = 0.6000$, $p = 0.2417$). The number of trees planted increased as the percentage of trees in the second largest size class (30-46 cm dbh) increased (Table 3.6). Approximately 9.4% of community tree budgets were dedicated to planting efforts.

No inventory community for which planting and removal records were available had a net gain in tree population. The median tree loss was 149 trees, with the tree populations of some communities decreasing by over 200, with one community losing more than 1,000 trees in 2007.

Tree Budget

Tree budgets for inventory communities ranged from $85,500 to over $1.5 million. Per capita tree spending varied, but all inventory communities spent at least $2.00 per capita. Tree budget for inventory communities was not associated with diversity or tree condition. Tree budget was associated with the 30-46 cm size class, but not with other size classes (Table 3.6).

Advocacy and Advisory Groups

Eight inventory communities had at least one advocacy or advisory group assisting with tree-related activities. One community had an inactive tree group that became active in late 2008. The greatest number of active tree groups in a community was three. As population increased, inventory communities were more likely to have more advocacy groups (ρ_s=0.6547, p=0.0781).

Tree Warden Credentials

While all managing communities met the CARS measures, which included a requirement for "professional staff," one community did not have a professionally-trained tree warden. That community, instead, had other professionally-trained staff. Tree warden credentials were not associated with environmental services or with the structure of the street tree population.

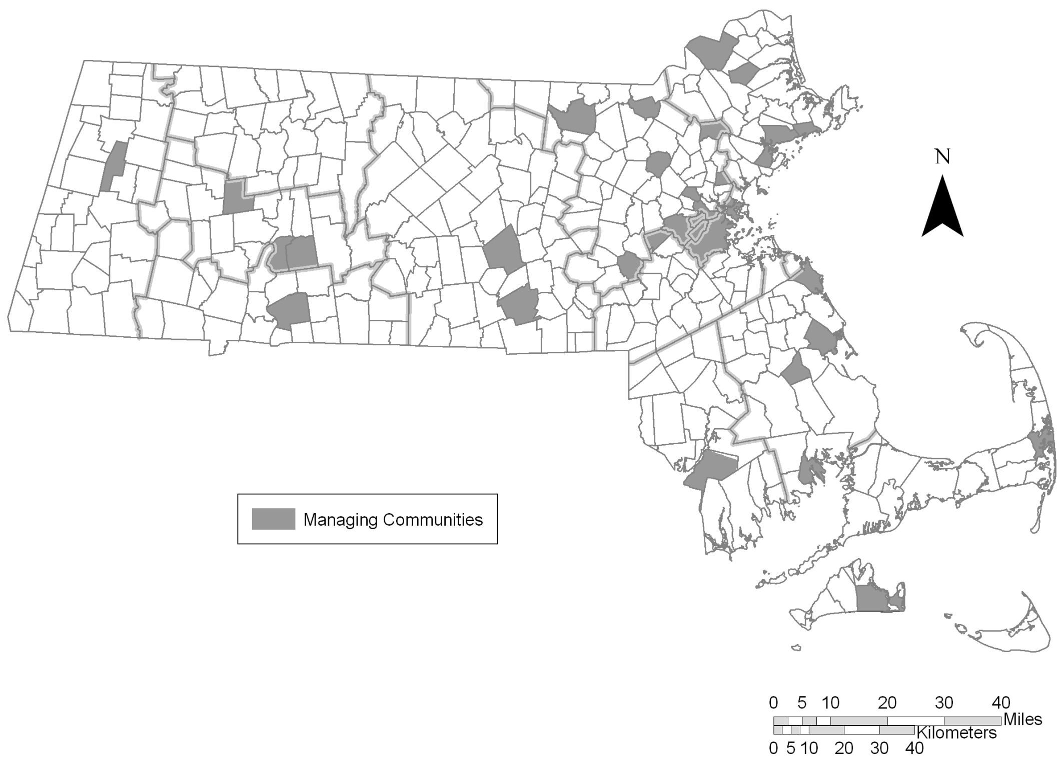

Figure 3. 1. Map of the 33 managing communities. Data source: Rines 2007, MassGIS, MA-DCR Urban & Community Forestry.

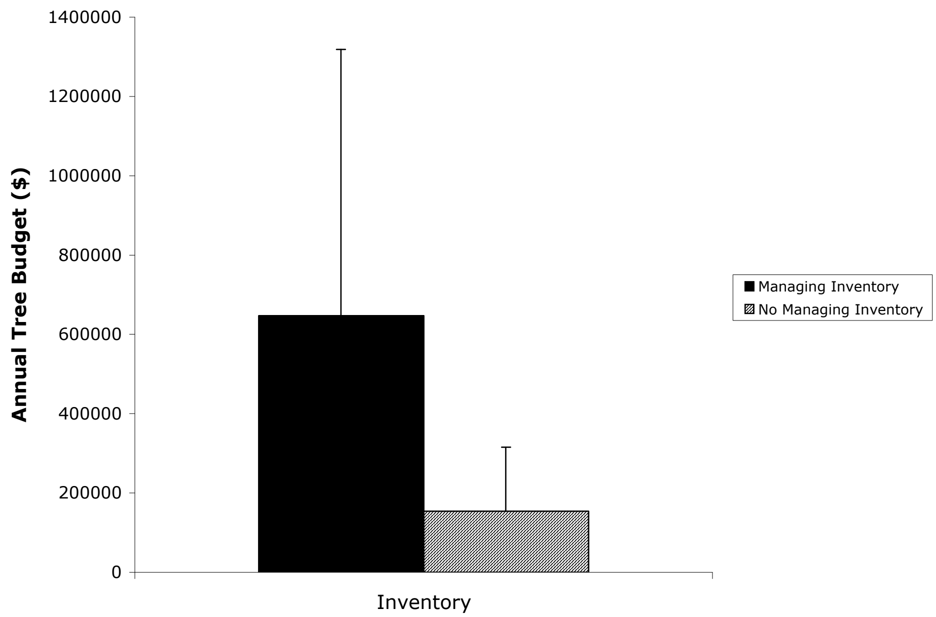

Figure 3.2. Mean (+ 1 SD) tree budgets for communities with and without managing inventories. There was a significant difference between tree budgets for communities with managing inventories and those without managing inventories (Wilcoxon rank sum test; $n_{managing} = 12$, $n_{non\text{-}managing} = 17$, $W=156$, $p = 0.0161$)

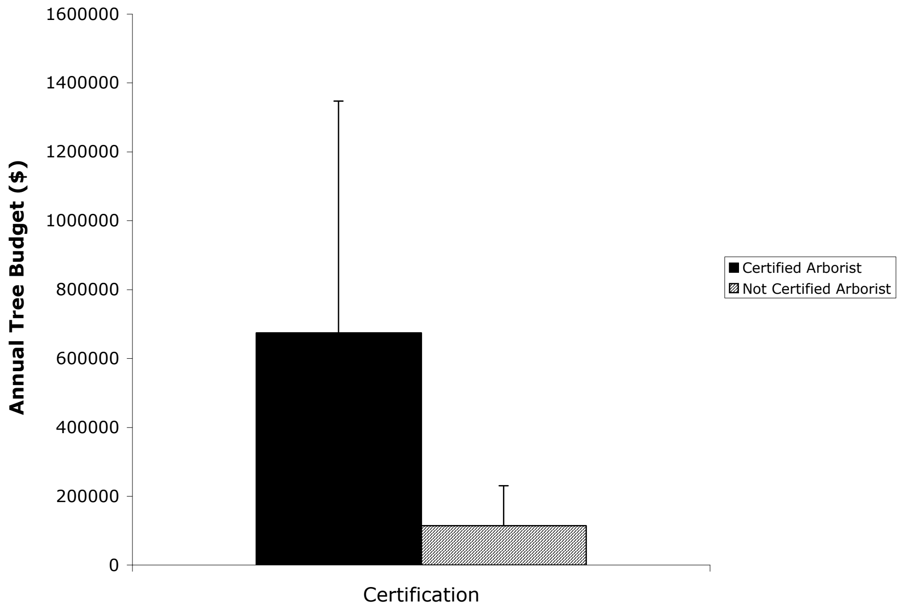

Figure 3.3. Mean (+ 1 SD) tree budgets for communities with and without tree wardens who were certified arborists (either ISA or MCA). There was a significant difference between tree budgets for communities with certified tree wardens and those without certified tree wardens (Wilcoxon rank sum test; $n_{certified}$=12, $n_{not\text{-}certified}$=16, W=159, p = 0.0026)

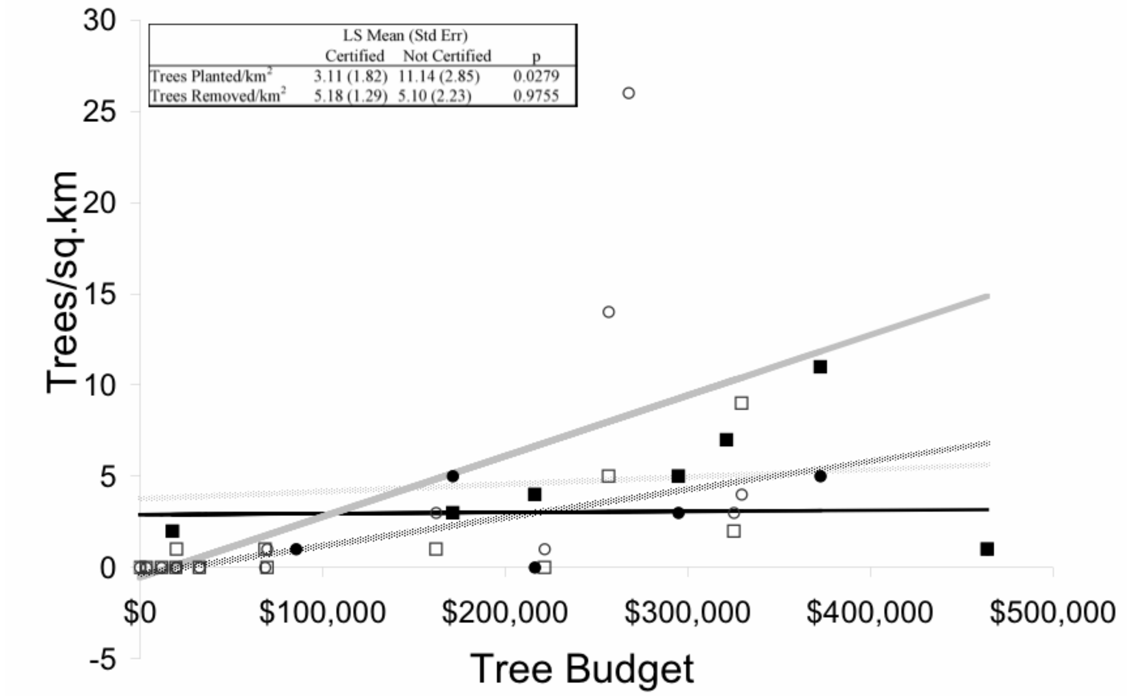

Figure 3.4. Trees planted (T_P, circles) and removed (T_R, squares) per km^2 for communities with tree wardens who were (●, ■) or were not (○, □) certified arborists, versus annual tree budget ($). Best fit lines to predict the number of trees per km^2 follow. For communities with tree wardens who were certified arborists: T_P=0.0000006$+2.90 (heavy solid line); T_R=0.0000040^z$+3.77^z (light solid line). For communities with tree wardens who were not certified arborists: T_P=0.0000332^{zy}$-0.53 (heavy dashed line); T_R=0.0000155^z$-0.35^z (light dashed line). Four outliers with budgets over $1 million were removed from the figure. The legend in the upper left corner of the figure presents least squares (LS) means for T_P and T_R for communities with tree wardens who were or were not certified arborists. ^{z}indicates that the coefficient was significantly ($p<0.05$) different from 0; ^{y}indicates that the coefficient was significantly ($p<0.05$) different between communities with tree wardens who were or were not certified arborists.

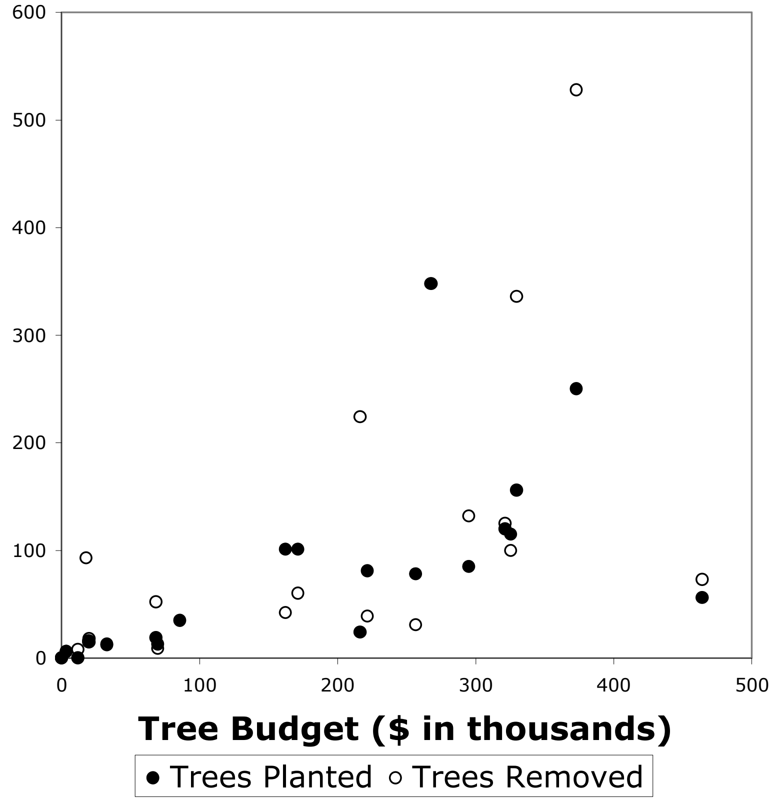

Figure 3.5. Trees planted and removed for managing communities. Four outliers with budgets over $1 million were removed. $n_{planted}$=24 , $n_{removed}$=23.

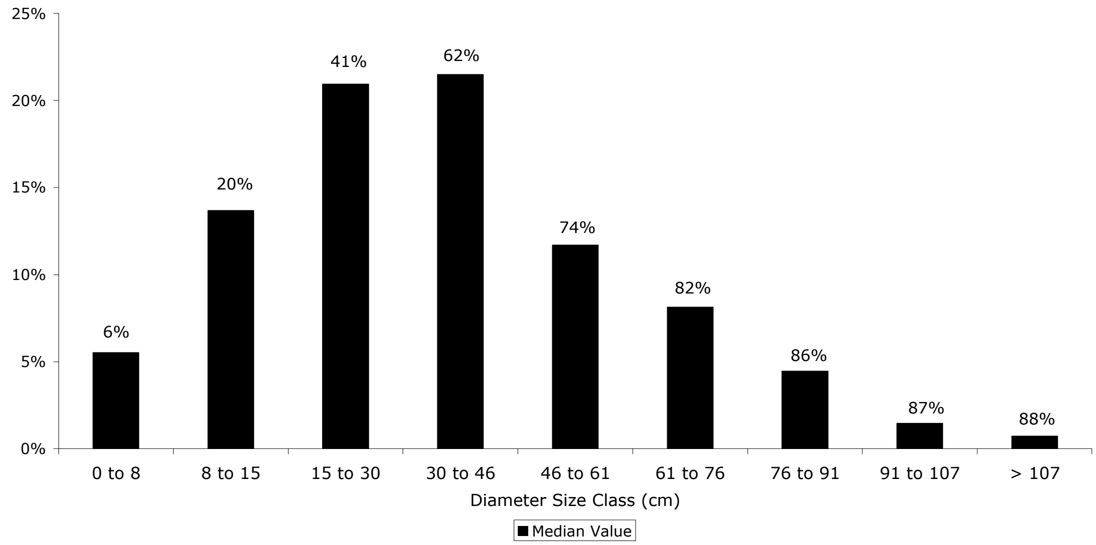

Figure 3.6. Size class distribution for trees in inventory communities by percentage of total trees. Bars represent median percentages for each size class. Percentage above the bars represents cumulative percent of the medians.

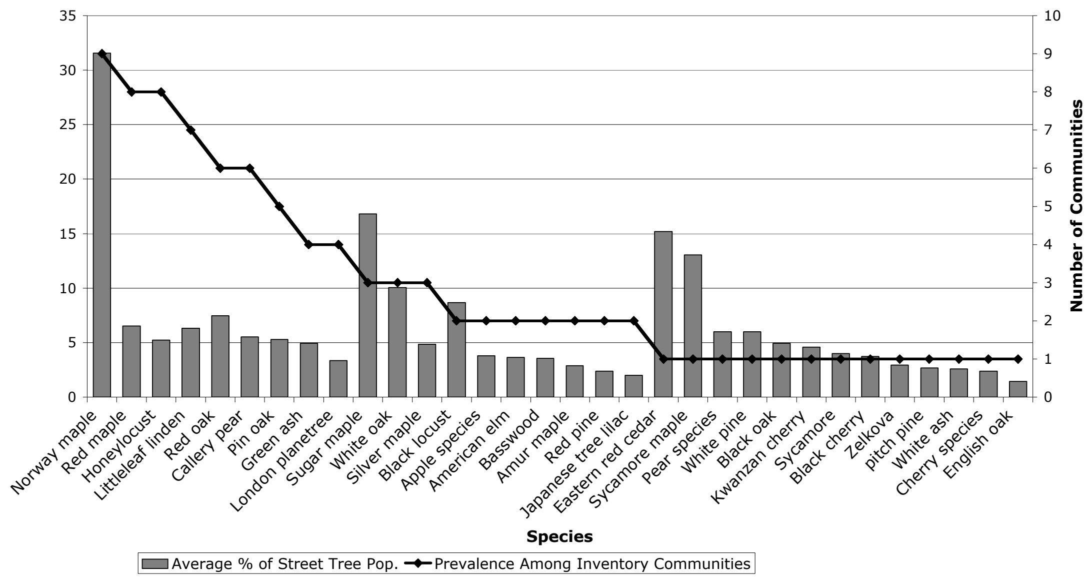

Figure 3.7. Mean percent of a community's street tree population that a particular species comprised (bars), as well as the number of communities for which the species was among the ten most common species in the community (line). Species are ordered according to the latter parameter.

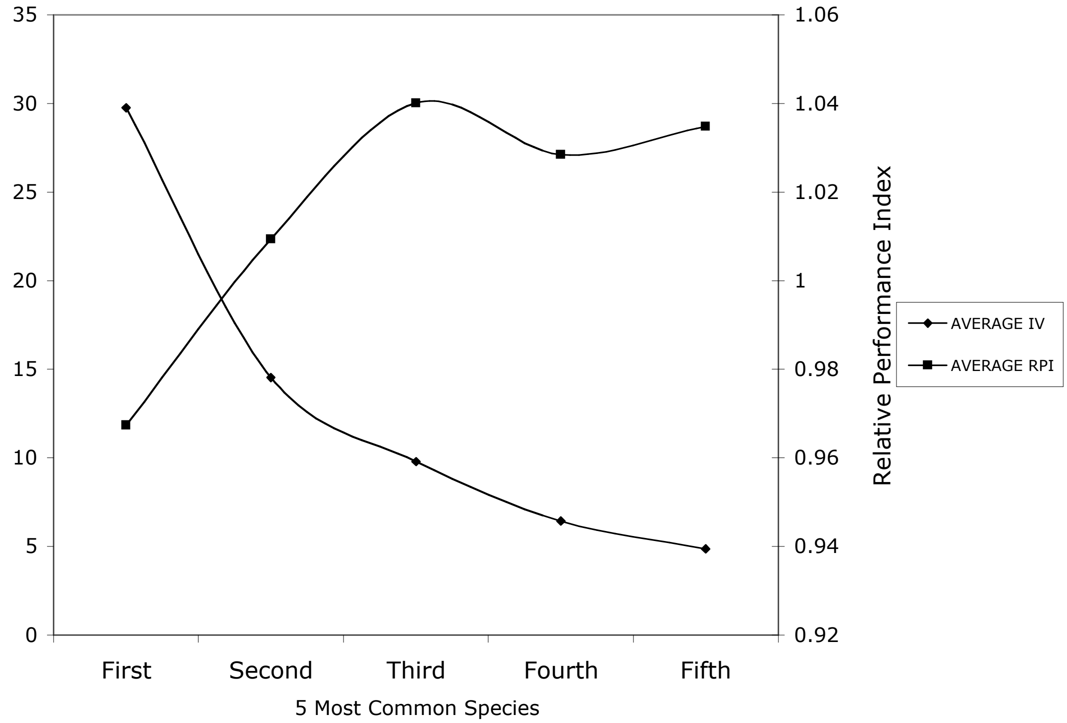

Figure 3.8. Mean Importance Values and Relative Performance Index values for the five most common species for inventory communities (n=9).

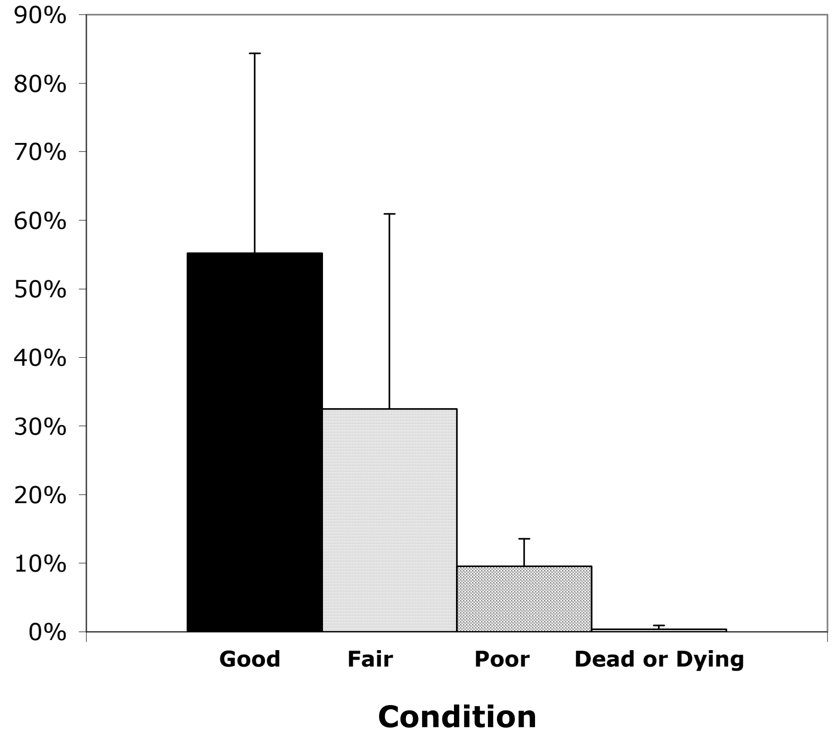

Figure 3.9. Median (+ 1 SD) of each tree condition for inventory communities, n=8. Percentage represents the median percentage of each class. Skewness values and p-values for condition classes were calculated using the D'Agostino test: Good, -0.5723, p= 0.5270; Fair, 0.8762, p=0.3360; Poor, -0.1372, p=0.8789; Dead or Dying, 0.5852, p=0.5179.

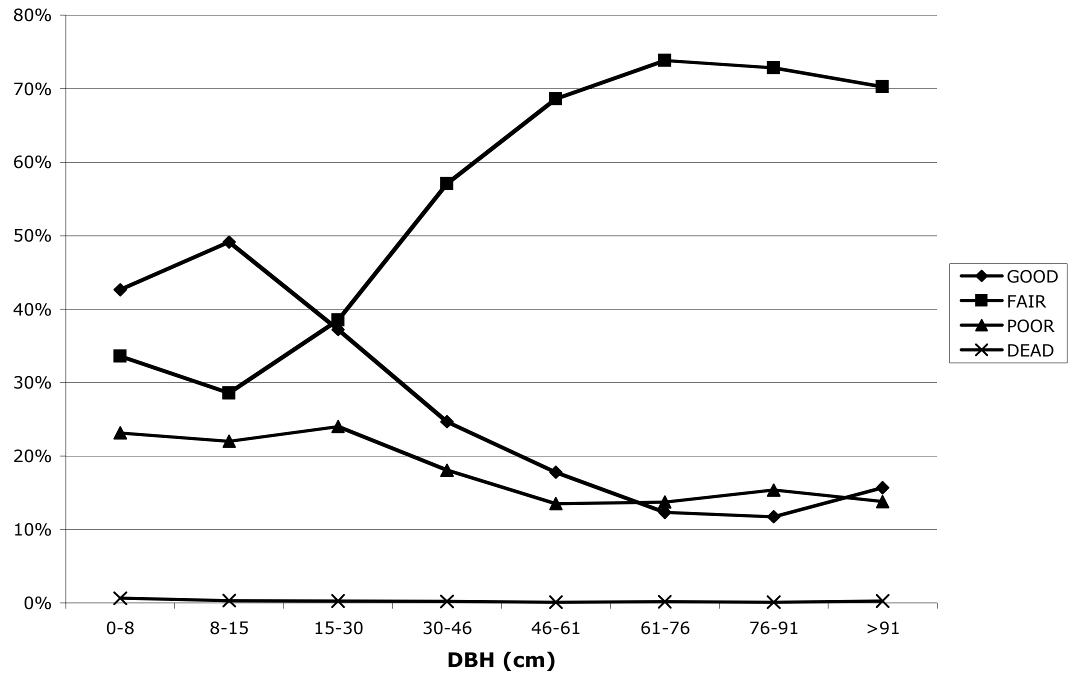

Figure 3.10. Tree condition within dbh classes. Aggregated percent of tree condition classes for all street trees calculated by percentage of condition in diameter classes, n=8.

Table 3.1 Inventory types for managing communities. The top three categories, complete inventory, sample inventory, and hazard tree inventory represent inventories used for management.

Inventory Type	Communities
Complete Inventory*	6
Sample Inventory*	3
Hazard Tree *	4
In Progress (Full Inventory)	2
Other	2
Old Inventory	4
None	12
Total	33

* Inventories used for management in 2007

Table 3.2. Medians of various demographic measures for managing communities and all communities in Massachusetts. W is the Wilcoxon coefficient, CI is the 95% confidence interval, and *P* is the p-value. The Wilcoxon Rank-Sum test was used to assess differences. Significance was determined at alpha = 0.05.

Demographic Data	**Managing Communities**	**MA**	***W***	**95% CI**	***P***
Population (2000)	17,196	9,707	65765	(-16154, 2028)	0.0031
Population Density persons/km^2)	403	194	65391	(-682.7, 79.5)	0.0004
Land Area (km^2)	53.2	41.4	5303	(10861, 7.288)	0.0853
Percentage of Population with Bachelors Degree	17%	20%	69571	(1.861, 7.288)	0.0010
Median Household Income (1999)	\$61,250	\$54,077	67121.5	(-10056, 4123)	0.4649
Population Change (1990-2000)	4.36%	6.73%	68655	(-0.238, 6.243)	0.0746

Data source: Year 2000 U.S. Census and Massachusetts State Data Center/Donahue Institute, University of Massachusetts President's Office

Table 3.3. Median, range and standard deviation for trees planted, trees removed, and the ratio of trees planted to trees removed (Planted/Removed), and tree budget for managing communities.

	n	**Median**	**Range**	**Standard Deviation**
Trees Planted	27	56	0-600	138
Trees Removed	26	56	0-1676	354
Trees Planted-Trees Removed	25	-5	-1,445-59	296
Tree Budget	29	216,339	0->1.5 mil	502,968

Table 3.4. Spearman rank correlation coefficients (ρ_s) describing associations between demographic variables, tree budget, and the number of trees planted and removed. All managing communities were included in the correlation matrix. Significance was determined at alpha = 0.05.

	Trees Planted (n=27)		**Trees Removed** (n=26)		**Tree Budget** (n=29)	
Demographic Variables	ρ_s	*p*	ρ_s	*p*	ρ_s	*p*
Population (2000)	0.8229	<0.0001	0.7941	<0.0001	0.9005	<0.0001
Median Household Income	-0.2508	0.2071	-0.1347	0.5116	-0.3217	0.0892
Percent bachelor degrees	-0.2520	0.2048	-0.1033	0.6156	-0.1744	0.3640
Tree Activity Variables						
Trees Planted	n/a	n/a	0.8203	<0.0001	0.8817	<0.0001
Trees Removed	0.8203	<0.0001	n/a	n/a	0.8567	<0.0001

Table 3.5. Median, range, and standard deviation for tree and budget variables for inventory communities.

	N	Median	Range	Standard Deviation
Simpson Index for Species (1/D)	7	9.61	1.61 - 9.87	3.63
Simpson Index for Genera (1/D)	7	5.57	1.54 - 5.99	1.91
Canopy Cover as a % of Linear Miles of Street	9	15.00	5.75 – 35.00	9.00
Tree spending per capita ($)	9	8.20	3.08 - 13.99	3.70
Benefit-Cost Ratio ($)	9	3.23	0.82 - 18.22	5.48

Table 3.6. Spearman rank correlation coefficients (ρ_s) for associations between tree variables (diversity, tree condition, and size class) and trees planted and removed, tree budget, and demographic variables (population, median household income, and percentage with bachelor's degrees). The tree variables tree condition, and size class are calculated as the percent of the total. Significance determined at alpha = 0.10; only inventory communities are included in associations.

		Trees Planted		**Trees Removed**		**Tree Budget**		**Population**		**Median Household Income**		**% Bachelor Degree**	
		ρ_s	*p*	ρ_s	*p*	ρ_s	*p*	ρ_s	*p*	ρ_s	*p*	ρ_s	*p*
Diversity (n=7)		-0.6000	0.2417	0.0000	1.0000	0.0357	0.9635	-0.2500	0.5948	0.0357	0.9635	0.1071	0.8397
Condition (n=8)	**Good**	-0.2381	0.5821	-0.5429	0.2972	-0.2381	0.5821	-0.2857	0.5008	0.4048	0.3268	0.6667	0.0831
	Fair	0.1429	0.7520	0.6000	0.2417	0.2381	0.5821	0.1667	0.7033	-0.1905	0.6646	-0.5476	0.1710
	Poor	-0.0238	0.9768	0.0286	1.0000	-0.2619	0.5364	-0.1190	0.7930	-0.0714	0.8820	-0.3571	0.3894
	Dead	-0.3095	0.4618	0.4286	0.4194	0.3810	0.3599	-0.1905	0.6646	-0.5476	0.1710	-0.4286	0.2992
Size (cm) (n=9)	**0-15**	-0.4048	0.3268	-0.4286	0.4194	-0.2000	0.6134	-0.2667	0.4933	0.0833	0.8432	0.2833	0.4630
	15-30	-0.0952	0.8401	-0.2571	0.6583	0.0333	0.9484	0.0167	0.9816	-0.1500	0.7080	-0.1167	0.7756
	30-46	0.6667	0.0831	0.4286	0.4194	0.6667	0.0589	0.6167	0.0857	0.1500	0.7080	0.0167	0.9816
	>46	0.0952	0.8401	0.0286	1.0000	0.0333	0.9484	0.0667	0.8801	0.0667	0.8801	0.1667	0.6777

CHAPTER 4

DISCUSSION

Introduction

Managing communities represented a high level of urban forest management in Massachusetts. This study aimed to show how that level of management was reflected in street tree populations in communities in Massachusetts. Results from this study show variability among managing communities in capacity for planting and removal and also in the structure and condition of street tree populations.

Characteristics of Managing and Inventory Communities

Though there may be some remaining bias due to the self-selection from the survey in 2006, managing communities did reflect characteristics of Massachusetts communities overall with respect to land area, population change, and median household income, however, managing communities tended to be denser and more populated than communities in Massachusetts. That managing communities were more urbanized suggests a relationship between meeting CARS measures and demographics. The nature of the CARS measures may lend themselves to be met by communities with the capacity to enact such measures. Rines et al. (2007) found mixed results with regard to population and median household income and attainment of the CARS measures. Reeder and Gerhold (1993) found cities in Pennsylvania more likely to have tree care programs than the less urbanized townships and boroughs. Active tree programs have also been associated with communities with populations over 10,000 in Utah (Kuhns et al. 2005).

Inventory communities were primarily located in and around urban clusters, most noticeably around Boston. The same bias due to differing capacity levels that appeared for managing communities may be the cause. This project required communities to have a recently updated, computerized inventory, a requirement that may have eliminated smaller, less urbanized communities from being classified as inventory communities. In neighboring Connecticut, inventories were present in 19% of municipalities, however only 14% of the inventories were computer-based (Ricard 1994). In the past, many studies that explored inventory use among communities in the United States focused only on inventory presence and not on the nature of the inventories—computer-based or paper-based—making thoughts on capacity and inventory type only speculation at this point (Schroeder et al. 2003; for a review of urban forestry practices in the United States, see Elmendorf et al. 2003.)

Tree Inventories

Inventories for communities were conducted in various ways over different periods of time. One inventory was for a downtown area only, which may reflect different planting opportunities and conditions for trees in that community. There are some limitations of using existing inventories for analysis, especially concerning some inventory categories, such as tree condition, that may be subjective and reflect tree warden experience and opinion. For condition classes, there may be reasons not to report some conditions, such as dead or dying trees, as that may be an implicit statement of liability. In fact, one community reported zero dead or dying trees. The method of using recently updated tree inventories was selected to take advantage of the inventories urban forest managers used to manage public trees. The inventories may thus reflect different styles of management, however, STRATUM required objective, basic inventory information, with the exception of tree condition, which may be a subjective field. A more comprehensive study may include the creation of sample inventories for communities, thus eliminating some of the factors that may vary due to tree warden opinion or experience.

Tree Budget

Managing and Inventory Communities

The result that tree budgets averaged 0.2% of municipal budgets was consistent with Tschantz and Sacamano's (1994) finding in their national study. Tree budgets varied among managing communities, with one community operating without a dedicated tree budget. It is difficult to imagine an effective municipal tree care program without a tree budget. Lewis and Boulahanis (2008) identified tree budget as one of the best predictors of routine tree maintenance in small southern towns. In Mississippi, communities stated that inadequate funding was the limiting factor in urban forestry programs (Grado et al. 2006). Without dedicated funding, communities may only practice reactionary management. In this project, the community that did not have a dedicated tree budget also had no planting and removal activity in 2007, and one can only speculate that little, if any, basic tree care took place in that community that year. Even with dedicated tree budgets, communities identified that they worked with utility companies and volunteer groups to handle some maintenance, planting, and removal activities. This type of cooperation is important for program stability as Treiman and Gartner (2004) noted that tree budgets from the general revenue stream might be impacted by tight budget years. With partnerships, tree wardens can continue to carry out urban forestry programs when communities allocate tree budget dollars to other departments. These types of partnerships, in addition to the support of active volunteer groups, may be more important than advocacy groups alone in maintaining an adequate level of urban forest maintenance. While this type of cooperation was not a focal point of this study, many tree wardens identified such partnerships in their programs. Kuhns et al. (2005) found that less populated towns spent the most per capita on tree care, a result that was not consistent with managing communities in Massachusetts where spending did not appear to fall into such a pattern. The finding in Massachusetts was consistent with national trends (Tschantz and Sacamano 1994). All but four managing communities spent the minimum of $2.00 per capita, a threshold The National Arbor Day Foundation uses for participating communities in its Tree City USA program (The National Arbor Day Foundation n.d.). All inventory communities were Tree City USA participants, and subsequently, all had per capita tree budgets above $2.00.

The association between tree budget and certification was not surprising, but whether the certification is the result of increased capacity or the increased need for high-level urban forest management in populated cities is more difficult to parse out. More populated communities may be likely to have greater tree budgets due to increased urban forestry needs in urbanized areas. A certified urban forest manager may be desirable in more urbanized areas due to increased pressures on urban trees and increased risk due to the greater concentration of people. It is likely that the relationship is not the result of capacity alone (i.e., that more money can support a certified tree warden), but that communities with greater tree budgets are likely to be more urbanized with greater pressures on trees, increased risk and thus, require a certified tree warden.

This result is supported by results in Illinois and Oregon where larger communities were more likely to have certified arborists in management positions, on staff, or on contract (Schroeder et al. 2003; Ries et al. 2007).

Tree Planting and Removal

Managing Communities

Tree planting and removal data for this study represent a baseline for determining future trends in urban forest populations. Examining only one year of data may single out anomalous years for some communities that may have less of an impact when averaged over time, however there is no reason to believe that 2007 was for any reason an anomalous year in Massachusetts. For communities to have a stable or a growing urban forest population, at the most basic level, they should be replanting trees that are removed or ensuring that lost canopy cover will be replaced by future trees. That communities in Massachusetts removed more trees than they planted was consistent with findings in Pennsylvania (Reeder and Gerhold 1993), but not with findings in Illinois where communities stated they planted 2.7 trees for each tree removed (Schroeder et al. 2003). Looking at total canopy cover or canopy cover on a smaller scale, such as shading of streets and sidewalks, may be a more holistic way of quantitatively assessing street tree populations. Raw planting and removal numbers give a sense of tree activity in a community, but may not accurately represent the quantity of urban forest or the future benefits to be derived from trees. It is likely that the dbh and the resulting canopy cover of trees removed in managing communities was greater than trees that were being planted, indicating a loss of ecosystem services, at least in the short-term.

Residents often value street trees (Treiman and Gartner 2005), however this value is not addressed by a basic calculation of net change in tree population. If communities planted smaller-sized trees and removed large shade trees, that would not be reflected in raw tree numbers, but would result in less canopy cover and fewer ecosystem services. In many instances, it may not be appropriate to replace a large shade tree that had been planted in an inappropriate location. A community with large shade trees planted below utility wires may not replace those trees as they reach maturity and are removed. Those sites may be replanted with smaller trees, or they may be removed from the pool of suitable planting sites. Bartsch et al (1985) used a measurable value, percentage of shade on public pavement for a city block at a given time on a given day, to assess canopy needs for Palo Alto, CA. This approach included a benefit that the community valued, shaded pavement and sidewalks, and enabled the development of a meaningful, measurable standard based on a direct benefit to the public. This type of standard may be more labor intensive, but could result in targeted plantings in areas of communities that fall below the standard. This standard also directly addresses the benefits that the city wanted to derive from trees. Similarly, a canopy cover analysis can provide information about areas lacking trees and this type of analysis has been utilized in urban forestry in the United States for decades (Harrell and Gornicki 1981). Other types of analyses can be useful as well such as that used in an analysis in 2008 of urban and community forests in Massachusetts. The report identified communities with inadequate tree canopy, using an index based on population density, canopy cover, and pervious cover (Nowak and Greenfield 2008). Many managing communities were identified as priority planting areas and the results underscored the importance of tree planting in managing communities.

It was not surprising to see tree plantings and removals increase with tree budget as increased tree budget may reflect greater capacity for tree activity. Additionally, for managing communities, the positive relationship between trees planted and trees removed, perhaps indicated some trend toward equalizing gains and losses. However, most communities still experienced a net loss in trees. There were some elements that may confound the relationship between trees planted and removed as well as between planting and removal activities and demographic and budget factors. Tree planting numbers may include trees planted in conjunction with private groups and reflect plantings conducted with non-budget dollars. Tree removal numbers may also be confounded by cooperative efforts between utility companies and communities. For line clearance, utilities may remove trees that threaten power lines, representing a source of tree activity not tied to community tree budget.

Inventory Communities

As the relationship between trees planted and removed may be confounded by outside factors affecting activity in communities, the lack of relationship between planting and removal for inventory communities is also confounded by the same factors. However, in this study, the small sample size of inventory communities may limit the power of the Spearman test. That trees planted increased with the percentage of trees in the second largest size class may suggest that tree wardens planted trees as significant trees in their communities reach maturity and may be of an age where condition will start to decline, necessitating replacement. These may have been historic or otherwise prominent trees in a community that a tree warden will want to have a suitable replacement for when the time comes for removal. Communities with greater populations had higher tree budgets, so it is possible that less-populated communities had more suitable planting spaces available or more resources available for tree planting. Most of the inventory communities experienced a shrinking urban forest in 2007, but the gap between trees planted and removed for some communities is alarming if it is part of a continuing trend. There is no reason to believe that 2007 was an anomalous year for any of these communities, however, the removal of over 1,000 trees by one community could perhaps reflect added funding for removal of a backlog of trees that the community was unable to remove in prior years. However, large trees provide more benefits than smaller trees and it will take years for newly planted trees to begin to provide benefits on a large scale (Dwyer et al. 2003). A long-term strategy is needed to ensure that benefits are sustained over time.

Advocacy and Advisory Groups

Inventory Communities

Advocacy and advisory groups have been seen as important parts of urban forest sustainability (Elmendorf et al. 2003; Dwyer et al. 2000; Tshantz and Sacamano 1995). These groups can fulfill many niches in an urban forestry program working within and outside of the municipal structure to achieve urban forestry objectives. As community population increased in Massachusetts, so did the number of advocacy groups in inventory communities, however this study did not address the role and activities of tree groups. Communities with larger populations tended to have more advocacy and advisory organizations, however it may not be the number of groups that is important, but the activities and effectiveness of groups. Less-populated communities may only need one effective group to achieve some urban forestry objectives.

Tree Warden Credentials

Managing Communities

That certification was more likely as population increased has been shown in Illinois (Schroeder et al. 2003). In Massachusetts, this relationship was expected due to the co-linearity of tree budget and population. It was expected that communities that participated in The National Arbor Day Foundation's Tree City USA program would have higher planting rates, however, this could not be investigated due to only 7 non-Tree City USA communities.

It was expected that tree warden certification status would influence tree planting rates, however, the result that non-certified tree wardens planted trees at a higher rate than certified tree wardens was unanticipated. This could be explained by non-certified tree wardens working in smaller, more rural communities where there was more available planting space, or by non-certified tree wardens spending less time on maintenance tasks. In Massachusetts, Rines (2007) found that communities with populations greater than 10,000 inhabitants were more likely to have a certified tree warden. Additionally, 61% of tree wardens in communities with populations below 10,000 inhabitants placed "low to no priority" on preventative tree maintenance, perhaps indicating that time is being spent on other tasks. Rines found that attitudes toward planting did not differ between communities with populations above and below 10,000; approximately half of tree wardens placed "low to no priority" on tree planting. Rines also found that while importance of planting was similar for tree wardens in communities with populations above and below 10,000, tree wardens in the more populated communities placed higher priorities on tree management tasks such as "inspections of work performed" and "preventative tree maintenance" (Rines 2007). Examining data collected over several years may provide more insight into this result. The impact of certification status on tree planting activities should be further investigated to determine the nature of the relationship. Further examination of the nature of the interaction of certification and tree budget may shed some light on the influence of certification and the relationship of certification to tree budget. It was anticipated that there would be a relationship between certification and whether a community had an inventory used for management. This, however, was unfounded with managing communities. The small sample size in the study may explain the lack of relationship.

That non-certified tree wardens removed trees at a higher rate may suggest differing priorities in urban forestry programs. It may suggest an ability for communities to remove trees quickly as they become hazardous or it may suggest that trees are being removed rather than maintained over time. One year of data is not adequate to assess the nature of this relationship.

Inventory Communities

Urban Forest Structure

Street trees in inventory communities predominated in the middle size classes. Trees that were newly planted as well as large, mature trees were lacking. Without knowledge of specific street tree management plans for each community that might indicate optimal stocking levels for street trees, it was not possible to evaluate the quantity of trees that communities planted in 2007 in the context of urban forest management goals. From this study, it was not possible to discern whether communities planted enough trees to overcome removal rates, but I would speculate that some communities did not plant enough trees to overcome mortality of older trees and also of newly planted trees that failed to establish. Further investigation is needed to substantiate such claims.

The association between trees 30-46 cm and population is perhaps only statistically significant as there were no other associations between other size classes and population. Looking at median dbh values indicated a disconnect between trees greater than 46 cm and those in smaller size classes, possibly indicating a level at which trees that failed to thrive are removed or reflecting a past planting trend. Trees greater than 46 cm constituted a smaller percentage of total trees possibly indicating tree loss of more mature trees or indicating weaker past tree planting efforts. McPherson and Rowntree (1989) examined tree inventories from across the United States and found that diameter structure of tree populations fell into three patterns. The Type 1 pattern consisted of a populations with over 40% young trees (<15cm) and nearly 30% of trees in the next youngest size class (16-30cm). In the Type 1 pattern, the proportion of trees in larger size classes consistently decreases. The Type 2 pattern consisted of trees predominantly in middle size classes and the Type 3 pattern consisted of trees distributed across size classes, with a higher proportion of trees above 45cm than the other two patterns. Results in Massachusetts showed that street tree populations belonged to the Type 2 pattern found by McPherson and Rowntree (1989). This pattern included fewer newly planted trees, with trees increasing in the middle size classes and declining above 46 cm. For comparison, McPherson and Rowntree (1989) found that for Type 2 communities, trees in the smallest size classes consisted of approximately 20% of a tree population, a result that comports with data from Massachusetts. This pattern of age structure is not the pattern Richards (1983) recommended for a diverse urban forest based on observations in Syracuse, New York. Richards advised that 40% of trees should be smaller than 20 cm to overcome mortality. While Richards's recommendation makes logical sense because of establishment mortality and other causes of urban tree death, further inquiry is needed to determine the dynamics of urban forests on a regional scale.

Kielbaso (1988) found that for communities across the United States, planting consisted of 14% of tree budgets. The value in Massachusetts of 9.4% for inventory communities showed fewer municipal funds being used for planting, but communities in Massachusetts also received assistance in tree planting from local non-profit organizations and other sources not tied to the municipal tree budget. In some cases, managing communities did not have planting programs at all and solely relied upon planting efforts of tree groups. Vitsoh and Thompson (2000) found that Iowa communities that received outside funding to plant trees also increased other urban forestry activities. In addition to activities such as the creation of a tree board or attainment of Tree City USA status, some communities in Iowa were able to enhance tree programs through establishment of a dedicated tree budget. Seeking outside funds for tree planting indicates a level of activism in a community urban forestry program, as does cooperation with local groups. This type of activism may be important in sustaining urban forestry programs.

Diversity

Species distribution among inventory communities was similar to what McPherson and Rowntree (1989) found for the northeastern United States. They observed that maples species made up half of the ten species most often occurring in the northeast. They found that Norway maple (*Acer platanoides*) was one of the trees most often planted. Data for inventory communities supported this trend with maples comprising the top two most frequently occurring species. While this study did not address species distribution among diameter classes, the proportion of Norway maples among newly planted trees should decline with a state ban on the planting of the species due to its invasive nature (Massachusetts Department of Agricultural Resources n.d.).

That diversity of genera was 42% less than the diversity for species indicates a reliance on fewer genera and was most likely the result of the preponderance of trees in the *Acer* genus throughout the inventory communities. This is consistent with the findings of Raupp et al. (2006) who found that trees in the *Acer* genus were the most common street trees in cities in eastern North America. Genus as well as species diversity is important in preventing widespread tree loss due to pests that are not species specific, such as Asian longhorned beetle (*Anoplophora glabripennis*) and emerald ash borer (*Agrillus plannipennis*). Emerald ash borer attacks ash trees (*Fraxinus* spp.), while Asian longhorned beetle attacks trees in many genera including maple (*Acer* spp.), birch (*Betulus* spp.), and elm (*Ulmus* spp.) among others (McCollough et al. 2008; USDA Forest Service 2008). Species diversity alone would likely not be enough to buffer against impacts of these particular pests.

In ecology there are caveats of using indices to measure diversity and conclusions about diversity derived from different indices can vary depending on the nature of the index (Magurran 1988). The use of ecological diversity measures for urban forests has been criticized due to the non-natural condition of urban forests (Richards 1993). This study examined species diversity at the community level, but investigating diversity at multiple scales, such as at the neighborhood or street level, may provide valuable information on diversity at smaller scales. Gartner et al. (2002) used diversity measures at different scales in communities in Missouri. The average index value of 9.34 in Massachusetts is similar to results found in Iowa (Thompson et al. 2004). Tree diversity can include characteristics in addition to species such as genus or family or size at maturity. Richards (1983; 1993) has discussed reliance on the use of species as the sole measure of diversity and pointed to other factors that contribute to diversity in urban forests, including age, site conditions, and urban forestry objectives. Site conditions may include not only the type of planting space, but also on a larger scale the neighborhood, or the land use for an area. Thus, species diversity for inventory communities represented only one facet of diversity. A value of diversity incorporating these other factors may increase the total diversity for some inventory communities. In the context of this study, current diversity is not a reliable reflection of current management, but is the legacy of previous management. An examination of tree species and cultivars that current managers plant may provide insight into the future diversity of urban forests. A model incorporating species planted with expected mortality of newly planted trees and mature trees may be able to guide planting so managers can reach diversity goals as well as goals for canopy cover.

While there may be more holistic ways to measure diversity in an urban forest, a diversity of trees remains important. The experience of Dutch elm disease (*Oophiostomoa ulmi)* in communities that were reliant on American elm (*Ulmus americana*) along with the more recent examples of emerald ash borer in the Midwestern United States (Cappaert et al. 2005) and Asian longhorned beetle in Worcester, Massachusetts and elsewhere show a need for tree diversity at both the species and genus levels. Raupp et al. (2006) examined street tree populations to assess risk to emerald ash borer and Asian longhorned beetle and found that most communities were susceptible to substantial tree loss due to both emerald ash borer and Asian longhorned beetle. Managers may be able to mitigate the impacts of these pests by utilizing a variety of species and genera in a diversity of settings in urban areas.

One factor that limits species diversity in urban settings is the limited selection of well-adapted species for the difficult conditions that street trees endure. Richards (1983) cautioned against selecting trees in the name of diversity that may not be well-adapted for urban conditions. Low species diversity, especially in larger size classes as Richards found in Syracuse, was likely the result of few species being able to thrive and reach a mature size in an urban setting. Adaptability to urban conditions is an important consideration for street trees, as street trees face challenging conditions (Miller 1997). Communities will have to weigh the potential benefits and costs of increased diversity against the use of species known to have high durability and survivability. Instead of increasing diversity by adding new species, communities may improve diversity by increasing the evenness of the population of street trees. Evenness is another component of diversity that accounts for the parity of species abundance. Communities can plant durable species that are less well-represented in the street tree population and increase parity of that species to others.

Richards (1993) encouraged local testing of species to assess suitability for street tree planting. This type of testing would be especially useful in Massachusetts where reliance on maples puts communities at risk for catastrophic tree loss due to potential infestation of Asian longhorned beetle. Communities can experiment on small scales by planting less-traditional or “untested” species for street trees, however a more rigorous, systematic inquiry may provide more reliable results on longevity and ability to survive urban conditions. This type of experimentation may become increasingly important in the face of climate change.

Importance Values

The gap between importance values for the first and second most common species suggested that communities relied on one species for a large portion of environmental services. This pattern of codominance has been found in cities in the western United States (McPherson et al. 2005). While the most common species provided a large portion of environmental services, the most common species was in the worst condition relative to other common species. The most common species was perhaps the species also exhibiting longevity and durability, although with declining quality as it reached and passed maturity. In inventory communities, this may be explained by the presence of mature and over mature Norway maples heavily planted following tree loss to Dutch elm disease. That the first and second most common species provided nearly 50% of environmental services for communities sets communities up for a potential management disaster and loss of ecosystem services should an insect or disease impact those species. This pattern of codominance may change as communities work to diversify their urban forests and as communities in Massachusetts respond to the presence of Asian longhorned beetle in Worcester.

Benefits

One community did not receive more in benefits than it paid in costs to maintain its urban forest. The biggest limitation to benefits trees provided appeared to be the number of trees as well as the size of trees, with larger trees providing more benefits. A community with a negative benefit-cost ratio may be at an earlier stage of development, consisting of smaller trees. Storms, tornadoes, and insect and disease outbreak may result in large-scale loss of municipal trees over a short period of time. Over longer periods of time, in communities where management does not prioritize planting, tree populations may decline as large trees are removed without replacement. A community in a position of rebuilding its tree population may incur losses as the initial investment is not countered by initial benefits. As aesthetic benefits (based on median single-family home sale price) consisted of the largest portion of benefits for communities, a community with a low home sale price may not reap high monetary rewards. The community may be adequately managing its trees, but may be severely impacted by the low aesthetic benefit. It may be hard to justify funding for an urban forestry program if an urban forest does not provide benefits, at a minimum, equal to the cost of its management, however the population structure and development of the population of street trees has to be taken into account. This type of analysis ignores the intangible benefits of urban forests, such as psychological benefits, however, community budgets may not take into account such benefits.

Condition

The finding that trees in good and fair condition consisted of the bulk of reported conditions is encouraging, however examining tree condition across diameter classes raised some concerns. Tree condition in inventory communities declined as diameter classes increased. The decline in condition class for trees greater than 15 cm indicated that after establishment, trees failed to thrive. Difficult urban conditions have been detailed (Miller 1997), and many factors contribute to tree establishment or failure, some of which may be related to tree stock, the planting process, or type of planting space and quality of soil. The sharp decline in trees in "good" condition may reflect any of these factors. It may also reflect the limit to a street tree's growth in difficult planting sites such as tree pits or narrow tree lawns where available root space is limited. This decline may also have implications for planting. Current planting efforts may not be enough to maintain a high level of benefits over time. These results appear to differ from tree conditions Gartner et al. (2002) found in Missouri, however, that study contained two additional condition classes. In that study, trees classified as "good" remained fairly flat, while trees in excellent condition declined by 66% from smallest to the largest diameter class. One might expect if urban forests in Massachusetts consisted of common, durable urban species condition would not decline so sharply, however the limitation of available root space and difficult urban conditions would still be present. This may be supported by the results for trees in fair condition whose trajectory across condition classes showed nearly a mirror of trees in good condition. Large trees in inventory communities may have proven themselves by their longevity, however, their condition indicates that they perform only adequately and not at an optimal level. At a coarse scale, this may be a sign of the difficulties that street trees encounter as they mature. At a finer scale, these trees may require more maintenance to limit potential hazards. It would be worthwhile to examine trees that reached the largest size class and remained in good condition to assess site and species factors. It may be difficult to overcome such a pattern given other contributing factors such as poor site conditions, planting stock, damage, or inadequate or untimely maintenance. Perhaps with more optimal site conditions, trees that are currently not considered desirable street trees could become viable.

Dead and dying trees constituted less than 2% of reported tree conditions for inventory communities, indicating that communities are able to remove the most hazardous trees, an important safety concern. (For all but two communities, this figure was less than 1%). There was a wider range for trees in poor condition and this may indicate that some communities had difficulty managing potentially hazardous trees. While the condition scoring does not indicate whether a tree is hazardous or not, one may surmise that a street tree in poor condition may be one that poses a public hazard. Street trees inherently have potential targets, such as pedestrians and vehicles, and should be a priority in municipal tree management. Only two inventories recorded a hazard rating leaving the other seven communities without a system to prioritize management. In the face of budget pressures, the use of a hazard rating system to manage trees may help a community target maintenance where it is needed most.

Community Wealth and Education

While community wealth and education were not associated with tree condition, these variables were positively associated with overall net benefits per tree. This could partly be explained by the impact of median home value, a variable associated with wealth and education, on the calculation of benefits within STRATUM. In Illinois, Dickerson et al. (2001) found that wealth was associated with ordinances serving to preserve and protect urban trees. From this result, one might expect community wealth to impact tree condition, however that was not the case in Massachusetts. One year of data was not enough to determine if this association may change over time.

Implications

While the Urban and Community Forestry program has been criticized for not showing measurable impacts on urban forests (U.S House of Representatives 2004), the current CARS performance scheme also does not allow for tracking urban forest performance. While CARS has made it easier to track developments in management programs, it tracks only management. It does not examine any resource-based components. Thus, the Forest Service is still left without a baseline of urban forest performance from which to measure future changes.

The results from this study show that street trees in a community may not adequately reflect the level of management in that community. Managing communities in Massachusetts had high levels of management, yet many had shrinking urban forests and large differences in tree planting and removal activities among communities. These communities represented the best management in Massachusetts, yet produced mixed results. When inventories were examined, they revealed tree populations that in many cases had few young trees, few large trees, and dominance of one or two species. Due to low diversity, many street tree populations were vulnerable to devastating losses from species and genus-specific insects or diseases. That many of these communities did not have tree inventories, even though they had responded yes to that question two years prior, indicates a reporting problem among responding communities. In its definition of management plans, however, the Forest Service has lumped inventories with assessments, such as analyses using remotely sensed data, thus communities may not have actually had an inventory in the first place. While assessments using aerial photos may help a community conduct long-term planning with regards to canopy cover, it does not lend much to the day-to-day management of trees and a key component of management plans is that communities actively use them. The definition is broad when it comes to what "active" entails, leaving many communities, as this study showed, without adequate management plans.

It is disappointing to find that when examined more closely, many communities identified as managing communities by CARS, were not actually managing communities. It shows some limits to assessing community performance using only self-reported surveys, however, given limited resources in Massachusetts, this is probably the most cost-effective way to assess performance. Additionally, the varied performance of communities detracts from the meaning of being classified as "managing" in the first place. One community operated without a tree budget and no subsequent tree planting or removals in 2007. Such programs should not be classified as "managing."

That it will take years to assess the impact of these CARS measures suggests that there may be additional measures that could be examined more quickly to ascertain urban forest performance and sustainability of programs. Such measures may include a budgetary component: per capita spending, sources of revenue, or per tree spending. They may include whether a community is a Tree City USA, a measure that includes budgetary and outreach requirements. Tree planting and removal activity may be another measure, as well as active partnerships. Many communities partnered with utility companies to assist with pruning and a few communities partnered with organizations to plant trees. Partnerships may enable communities to continue actively managing trees, even when tree budgets may fluctuate and municipal resources for planting are insufficient.

For Massachusetts, the CARS-based funding at stake is not huge. Massachusetts's share of CARS funding is approximately $250,000 (Eric Seaborn, pers. comm. 7/23/2010). Yet, this funding can be distributed to communities where it can make a difference. While it may be cost and labor intensive for state and national programs to track conditions in urban forests, without some ground-checking over time, the impact of these performance measures on urban forests will remain unknown.

Directions for Future Research

While this study aimed to assess street tree populations by inventory, it was limited to communities that met the other three CARS measures. An examination of existing inventories in Massachusetts or sampling communities across the state and across CARS performance levels may provide more insight into the condition of street tree populations in the state and the relationship, if any, of demographics to community performance. More thoroughly exploring community use of inventories may also yield interesting results as there appears to be a disconnect between the use of inventories and the academic argument for having one. Inventories are often promoted because it is believed that they can help communities prioritize management and minimize costs, yet these results remain somewhat nebulous and unproven for urban forest managers. A closer examination of the impact of tree inventories on management programs would help justify the importance of having one.

While this study showed that street tree populations varied among communities with high-level management programs, it is not possible to determine a cause and effect between management and performance at this time. This study may serve as a baseline for future examination of the nature of managing communities in Massachusetts and the legacy of high-level management on urban forests over time.

APPENDIX A

TREE WARDEN MEETING QUESTIONS

Inventory Questions

1. Is your community's tree inventory in electronic form or on paper? If it is electronic, what format is it in: Microsoft Access, Microsoft Excel, or another program?
2. Is the inventory a complete or a sample inventory? If it is a sample inventory is it random?
3. When was the inventory last updated?
4. Does the inventory contain information on hazardous trees or tree conditions in the community?
5. Are you willing to share the inventory for this study?

Tree Data Questions

6. How many trees did your community plant?
7. How many trees did your community remove?
8. What was the 2007 tree care budget? Do you have a line-item budget you would be willing to share?

APPENDIX B

THOUGHTS ON MEETINGS WITH TREE WARDENS

Meeting and speaking with tree wardens provided an opportunity to acquire inventory data and to discuss tree programs and tree wardens' thoughts on the CARS measures. This summary will focus on some opinions of tree wardens on inventories and advocacy groups. These are anecdotal thoughts on the meetings and do not represent a rigorous examination of opinions of tree wardens in Massachusetts.

I met with six tree wardens from across Massachusetts and spoke with 22 others and discovered that tree wardens were enthusiastic about participating and willing to share tree inventories and other information about community tree programs.

Tree Inventories

There appeared to be a difference in how rural and urban tree wardens viewed tree inventories. This difference was perhaps not surprising due to the different stresses facing urban and rural communities and differences in funding for tree urban and rural tree programs. In more urbanized communities, as population increases, so does liability, potentially shifting management concerns. Tree wardens in more urbanized areas characterized tree inventories as important management tools, while tree wardens in rural areas felt that inventories for management were unnecessary.

Tree Wardens in Massachusetts's larger and more densely populated communities all agreed on the importance of an up to date tree inventory for their daily operations and planning. Some communities already had an inventory and utilized it daily as part of organizing work orders and maximizing crew efficiency. There was one tree warden of a smaller, more rural community who had completed an inventory of downtown trees with the aim of justifying current levels of funding from the community. The tree warden was also looking forward to using the inventory for the department's work order system and streamlining the department's activities. This community may appear to be an outlier in its reliance on the inventory, but this community also experiences a population boom in the summer months, which may serve as a partial explanation. However, it would be impossible to pin the valuing of inventories solely on population, population density, or funding; for smaller, rural communities, the character of the tree warden and motivation may be more important in initiating and maintaining tree inventories.

Two other smaller, more rural communities did not have current, complete tree inventories used for everyday management. One community had an inventory of downtown trees near utility wires so the utility company could handle the pruning and removals. The tree warden conducted this inventory every spring and used it solely to direct the utility company activities. The other community did have a complete inventory from 1996, which the tree warden found useful when assuming the tree warden position. After becoming familiar with the community, however, the tree warden did not use the inventory and found driving around the community sufficient to assess the condition of public trees. This system may work for the tree warden, but will make transferring the position to another individual difficult.

Another tree warden from a smaller community, while valuing the inventory for his community, saw the greater value in an inventory for a larger community, where he believed a more systematic approach would be necessary. The tree wardens from larger, more densely populated communities supported that viewpoint, with their reliance on and respective use of their inventories.

Advocacy and Advisory Organizations

Some tree departments relied heavily on the work of community groups. This was especially apparent where budget constraints meant that the tree department could not put efforts toward planting. In one community the advocacy group handled all public tree planting because the department did not have funds to cover planting activities. The organization also cared for the trees for five years so that the tree department would not have to maintain the trees during their establishment. In other communities, activities of advocacy and advisory organizations supported and supplemented, rather than replaced, the work of the tree department as in communities with active tree planting committees or beautification committees. Many of these committees organized seasonal plantings and were responsible for planting memorial trees and gardens. Tree wardens in communities with active groups valued these organizations and the work they do. There was often much cooperation between the tree warden and community groups.

In some communities, organizations were present, but were not active. With fluctuating federal funds for urban and community forestry programs, communities may be looking for ways to not only meet safety obligations through preventative maintenance and timely removals, but also to adequately stock their streets with new trees. As several communities across Massachusetts have shown, this kind of relationship with community organizations this can mean the difference between communities with growing or shrinking tree populations.

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